Genetic Progress of Cotton Yield in Brazil

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ABSTRACT

Embrapa's cotton breeding program has made substantial progress in the last 18 years in developing cotton cultivars with higher yield and fiber properties. A parallel increase in resistance to drought and insect pests has also been obtained. Seed cotton yield and fiber property means of the cotton cultivar regional tests conducted by Embrapa in many locations of Northeast Brazil over the past 18 years was used to estimate the genetic progress achieved. These data show that the genetic progress for seed cotton yield over the 18 year period was 1.03% a year. Progress in fiber characteristics was also made.

Introduction

The cotton breeding program of Embrapa for Northeast Brazil. At that time Embrapa`s cotton (*Gossypium hirsutum L.*) breeding program for Northeast Brazil was initiated in 1976. The main emphasis was on developing cotton cultivars with high yield potential and improved fiber properties. Resistance to drought and insect pests was also prime objectives. The programme has been remarkably successful in improving fiber properties and yield potential over the last 18 years. According to the data presented in this paper, seed cotton yield increased at the rate of 1.03% a year. Fiber properties and fiber percentage experienced a significant rate of improvement as well.

There are many reports relating to this subject in the world literature. With respect to cotton, in a classical paper by Meredith & Bridge (1984), an annual progress of 0.74% in fiber yield from 1958 to 1980 in USA was reported. Genetic progress has also been reported in other commercial crops (Vencovsky *et al.*, 1988; Tolledo *et al.*, 1990; Rodrigues,1990; Abbud , 1991; and Soares & Ramalho, 1994).

The first cotton cultivars delivered by Embrapa in Northeast Brazil resulted in a very significant impact on cotton production. Among these cultivars were: BR-1, CNPA 2H, CNPA 3H, CNPA 6H, CNPA 7H and more recently CNPA Precoce 1 and 2. The objective of this paper was to estimate the genetic progress in cotton yield made by Embrapa`s cotton breeding program from 1976 to 1994.

Material and methods

Seed cotton yield and fiber property means of the Cotton Cultivars Regional Test conducted by Embrapa in several different locations of Northeast Brazil over the past 18 years were used to estimate the genetic progress in this work. The locations represent a wide range of diverse environments, including those with moderate to severe water stress and insect pressure.

The initial analysis of the final stand of each individual experiment revealed levels of significance in relation to this variable in some of them. All the trials were analyzed by using the mean stand as covariate (Vencovsky & Cruz, 1991). Once the adjusted mean for each location was obtained, the mean from each variety was compared across locations in each year. With these data, the Vencovsky *et al.* (1988) method to calculate the genetic progress was used. This method consists in evaluating the yield difference between genotypes in two consecutive years. This difference is used to calculate the total genetic gain. In each pair of years, the common treatments are used to estimate the annual effect to be subtracted from the total effect.

The method used to calculate the genetic progress is (Vencovsky *et al.* 1988):

$Y_1 = m+a_1+g_1+e_1$
Y_1 = General mean of trials in year 1
m = General mean
a_1 = The effect of year 1. Common to all treatments
g_1 = Genotypic mean effect of the lines (except the check) evaluated in the 1_{st} year
e_1 = Experimental error of the mean Y1 plus the mean of treatments interaction with year 1

In year 2, the same model was adopted,

$Y_2 = m+a_2+g_2+e_2$

With the effects described previously being the contrast:

$$Y_2 - Y_1 = (a_2 - a_1) + (g_2 - g_1) + (e_2 - e_1) \qquad (A)$$

What is of interest, is the determination of the g_2-g_1 difference that was observed between two consecutive years. From contrast "A", can be seen that the genetic differences are confounded with the environment differences. From the means of the common lines in the two years, and using this model it is possible to define their means as:

$Yc_1 = m+a_1+gc_{1,2}+e_1$

$Yc_2 = m+a_2+gc_{1,2}+e_2$

and also,

$Yc_2 - Yc_1 = (a_2-a_1) + (e_2-e_1)$ (B),

where:

Yc_1 = Mean of common treatments from year 1

Yc_2 = Mean of common treatments from year 2

$gc_{1,2}$ = Genotypic effect mean of common lines from year 1 and 2

The difference between contrast (A) and (B) estimates the genetic progress between the years 1 and 2 or $ag_{2,1}$ as following:

$ag_{2,1} = (Y_2 - Y_1) - (Y_{c2}-Y_{c1}) = (g_2 - g_1)$,

Since the experimental errors are randomized and suppose they are $N(\sigma,02)$. Therefore $ag_{2,1}$ may be taken as an estimation of the genotypic modification mean which occurred in year 2 in relation to year 1 as a consequence of the new materials included in year 2. During the 15 year period of the study, the genetic modifications $ag_{2,1}$, $ag_{3,2}$,.., $ag_{15,14}$ were obtained. The sum of these values represented the genetic progress accumulated or the total genetic gain (G_T):

$G_T = ag_{2,1}+ag_{3,2} + .. + ag_{15,14}$

which represents the yield increase in cotton within the period studied. The annual mean increase or mean annual gain (g_{ma}) can be obtained by dividing this value by the number of years in the period.

$gma = g_t/n-1$

The total genetic gain (G_T) and the mean annual gain (g_{ma}) can be represented as percentages by dividing their values by the general mean of the first year. In this work, as recommended by Soares & Ramalho (1994), the mean of the first two years was used to minimize the environment effect on the mean of the yield of the first year. The rate of strain substitution was also calculated by using the sequence of years in which the size of the experiment remained the same, in that sequence. The mean of those rates, in all the sequences these years, gave a substitution mean rate.

Results

Embrapa`s cotton breeding program has made substantial progress in creating and identifying recombinations of genes for higher yield potential and better fiber properties. Further progressive improvements have been achieved for other plant characteristics such as drought and pest resistance.

Several recent developments suggests that additional and major changes are expected to occur in the next few years in the field of adaptation to new environmental areas such as the “cerrados” in the Central West Region.

The results presented here are means of several Regional Cultivar Tests conducted over an 18 years period in Northeast Brazil. Data from these tests were used to estimate the genetic progress in seed cotton yield and some fiber characteristics within that period. According to the results, the genetic gain obtained in the whole period was 290kg/ha or 20.71%. This is equivalent to an annual average gain of 1.03% as shown in Table 3. During the whole period the percentage of strains replacement in the Cultivar Regional Test was 45%. This means that 55% of the genotypes were maintained in each pair of years.

Genetic progress has been quantified by breeding programmes for many crops around the world for many reasons, especially for the evaluation of the efficiency of the programme itself.

The genetic progress reported here can be compared to that of 0.7% a year obtained by Meredith & Bridge (1984) for cotton in USA Comparisons with many other commercial crops reveals a close resemblance. Genetic gains of 1.7% and 2.2% were reported by Vencovsky *et al.* (1988) for corn (hybrid and population); 1.3% to 1.8% for different soybean genotypes (Toledo *et al.*, 1990); 1.9% for Beans (Epaming, 1992); 1.4% to 5.0% for rice (Abbud 1991; Soares & Ramalho, 1994).

The incremental increase in seed cotton yield paralleled those in several other characteristics selected concurrently (Table 2). However, concurrent selection may have contributed to reduced potential yield of seed cotton. Among the characteristics selected with seed cotton yield, earliness as measured by the number of days for first boll opening decreased from 99 to 80 days. Boll weight jumped from 4.9g to 6.2g; fiber percentage from 34.7% to 43.2%; fiber uniformity from 51.2% to 52.8%; fiber micronaire from 4.6 to 3.9 while fiber strength and length were not improved (Table 1).

Recently, selections for higher fiber strength and earliness have been intensified to meet the demands of the textile industry and producers.

Conclusion

Results from our studies clearly show that over the 18-year period, the Embrapa breeding programme achieved significant genetic gains and continued improvements in seed cotton yield and fiber properties. Cultivars possessing genes with the potential to enhance fiber strength and resistance to insect pests and diseases will be a challenge for future cotton cultivar developments in Brazil.

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Table 1. Main characteristics of cultivars released by Embrapa in northeast Brazil from 1976 to 1994.

Cultivar	Year Released	A	B	C	D	E	F	G
BR - 1 (2)	1978	99	4.8	36.6	29.8	52.3	4.8	7.5
CNPA 2H (3)	1982	104	5.0	38.0	29.5	52.0	4.2	7.6
CNPA 3H (4)	1983	101	5.3	36.9	30.2	51.9	4.9	7.7
CNPA 6H (5)	1988	118	5.8	39.6	29.5	53.5	4.6	7.4
CNPA P1 (6)	1985	80	5.0	40.3	29.5	53.5	3.8	7.3
CNPA 7H (7)	1993	-	6.7	39.1	29.3	53.2	3.8	7.4
CNPA P2 (8)	1994	80	6.2	43.2	29.8	52.8	3.9	6.7

A - Days to first open boll (days)
B - Boll weight (g)
C - Fiber percentage (%)
D - Fiber length (2.5mm)
E - Fiber uniformity (%)
F - Fiber micronaire
G - Fiber resistance (lb/mg)
2 - Mean of 3 years in 25 locals
3 - Mean of 3 years in 13 locals
4 - Mean of 2 years in 6 locals
5 - Mean of years in 18 locals
6 - Mean of years in 18 locals
7 - Mean of 1 year in 2 locals
8 - Mean of 1 year in 2 locals

Table 2. Means of cultivars and strains $(Yi)_1$ adjusted in relation to the standard averange in each year of evaluation and of cultivars and strains which were common in sucessive pair of years ($Yci,i+1$, and $Yci,i-1$), genetic annual gain ($Gi,i-1$) and total from 1980 to 1994.

Year	Y_i	$Y_{ci,i+1}$	$Y_{ci,i-1}$	$G_{i,i-1}$ (kg/ha)
1980	1962	1947	-	-
1981	1778	1778	1732	31
1982	1163	1261	1163	0
1983	1817	1782	1833	82
1984	1084	1119	1047	2
1985	1419	1419	1395	59
1986	1419	1419	1399	20
1987	1793	1848	1793	0
1988	1769	1769	1791	33
1989	904	904	904	0
1990	2092	2083	2092	0
1991	1634	1634	1685	-60
1992	1878	2023	1878	0
1993	1563	1552	1585	123
1994	3218	-	3294	-
	Mean annual genetic gain in kg/ha			20,71
	Mean annual genetic gain in percentage			1,03

$_1 i = 1, ..., 15$.